

Influence of activated carbon moisture on microwave assisted decomposition of HDPE

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Research Article

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Abstract

This study examines the influence of activated-carbon moisture on the low-temperature microwave-assisted decomposition of high-density polyethylene (HDPE). Untreated and dried activated carbon were compared as microwave absorbers and catalysts. Moist activated carbon favoured n-alkane-rich wax, whereas dried activated carbon favoured gas production with a higher hydrogen yield. The wax obtained with dried carbon contained a larger aromatic fraction. The results indicate that activated-carbon moisture influences product distribution during microwave-assisted HDPE decomposition.

1. Introduction

Chemical recycling of waste plastics provides a route to gases and hydrocarbons through polymer-chain decomposition. Catalytic and microwave-assisted processes have been investigated to modify reaction conditions and product distribution [1–3].

HDPE requires a microwave absorber for effective heating. Activated carbon can serve this purpose and influence the formation of hydrogen and hydrocarbons [4]. Its moisture content may also affect microwave heating and surface interactions [5, 6].

This study compares untreated and dried activated carbon during low-temperature microwave-assisted HDPE decomposition, with emphasis on gaseous and wax products.

2. Materials and methods

2.1. Feedstock and experimental procedure

Waste HDPE caps were ground to below 1 mm after precooling with liquid nitrogen. Activated carbon (40–80 μm) was used either untreated (AC-W) or after drying at 105°C for 24 h (AC-D). Mixtures of 5 g HDPE and 5 g activated carbon were heated to 260°C at 10°C·min^{−1} and held for 30, 45 or 60 min under 3 vol.% O₂ in N₂.

2.2. Product and material analysis

Wax and solid residue were determined gravimetrically, and gas yield was calculated by difference. Gases were analysed by GC-FID/TCD, and waxes dissolved in toluene were analysed by GC-MS. Activated carbon and HDPE were characterized using Karl Fischer titration, thermal analysis, N₂ physisorption and NH₃ temperature-programmed desorption.

3. Results and discussion

3.1. Feedstock and activated carbon

Thermal analysis placed the main HDPE degradation interval above the measured bulk reaction temperature. Activated carbon released moisture at lower temperatures. Karl Fischer titration confirmed the lower water content of AC-D, while N₂ physisorption after degassing indicated comparable dry textural properties.

Temperature-programmed desorption indicated predominantly weak acidity, adsorbed water and oxygen-containing surface groups. These characteristics provide context for the interaction of water with the carbon surface [7].

3.2. Product yields and composition

Activated-carbon moisture affected product distribution. AC-W favoured wax formation, whereas AC-D favoured gas formation. Hydrogen was the dominant measured gas, with a higher relative yield for AC-D. Relative CO and CO₂ yields were higher for AC-W (Fig. 1).

The wax obtained with AC-W was dominated by n-alkanes. AC-D produced less wax, with a larger contribution of aromatic and polycyclic aromatic hydrocarbons. These differences indicate a shift between wax-rich and hydrogen-rich products.

3.3. Influence of moisture on reaction pathways

Moisture may modify microwave energy dissipation and interactions with oxygen-containing surface groups [5–7]. The differences in gas and wax composition are consistent with changes in secondary cracking and hydrogen-transfer reactions. Individual reaction steps were not resolved by the measurements.

Previous microwave studies have also reported condensable hydrocarbons and light gaseous products [8, 9]. Polyethylene decomposition can involve chain scission, hydrogen transfer and subsequent cracking or cyclization [10–12]. These pathways provide an interpretative framework for the observed products rather than direct evidence of a specific mechanism.

4. Conclusion

Activated-carbon moisture influenced the product distribution of microwave-assisted HDPE decomposition. Untreated carbon favoured n-alkane-rich wax and higher relative CO and CO₂ yields. Dried carbon favoured hydrogen-rich gas and a smaller wax fraction with a larger aromatic contribution. The results identify moisture content as an operating variable affecting product selectivity.

Declarations

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Figures

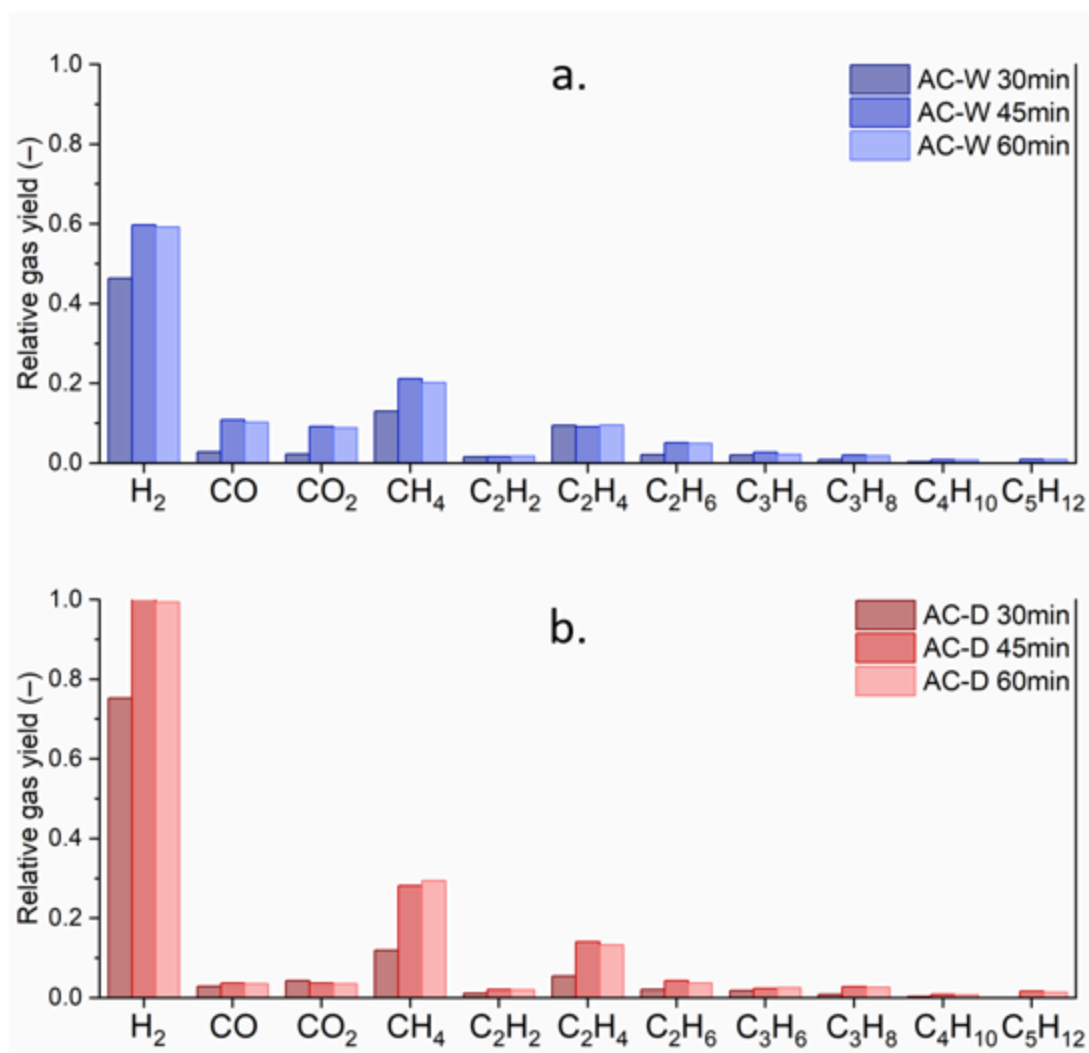


Figure 1

Relative gas yields obtained with untreated activated carbon (a.) and dried activated carbon (b.). Values are dimensionless and normalized to the reference maximum used in the supplied graphs.